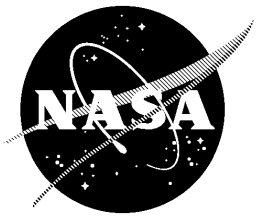
MISSION OPERATIONS AND DATA SYSTEMS DIRECTORATE

Earth Science Data and Information System (ESDIS)

Level 1 Product Generation System (LPGS)

Performance and Sizing Estimates

November 1997
(revised)



National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

Earth Science Data and Information System (ESDIS) Level 1 Product Generation System (LPGS) Performance and Sizing Estimates

November 1997

(revised)

Prepared Under Contract NAS5-31000/HQ001057

By Computer Sciences Corporation

Prepared by:

Walter Wang Date

LPGS System Engineer, CSC

Goddard Space Flight Center

Greenbelt, Maryland

Abstract

The Earth Science Data and Information System (ESDIS) Level 1 Product Generation System (LPGS) will be operated within the Earth Observing System (EOS) Ground System (EGS) . This will provide Landsat 7 Enhanced Thematic Mapper Plus (ETM+) systematically corrected digital images for distribution to the Earth Observing System (EOS) Data and Information System (EOSDIS) Core System (ECS) customers. This document contains the approaches, assumptions, and results of performance and sizing estimates for the LPGS.

Keywords*: Earth Observing System (EOS) Data and Information System (EOSDIS) Core System (ECS), Earth Science Data and Information System (ESDIS), Level 1 Product Generation System (LPGS)*

Contents

Abstract

1. Introduction

1.1 Scope 1–1

1.2 LPGS Overview 1–1

2. Documentation

2.1 Applicable Documents 2–1

2.2 Reference Documents 2–2

3. LPGS Performance Requirements

4. Modeling Approaches

4.1 Hardware Configuration 4–1

4.2 Process Flow 4–2

4.3 Mapping of Processes/Functions to HWCI 4–3

4.4 Approaches 4–5

4.4.1 Data Process 4–5

4.4.2 Data Transfer 4–5

4.4.3 Data Storage 4–5

4.5 Parameters and Assumptions 4–8

4.5.1 Image-Related Parameters 4–8

4.5.2 MSCD, PCD, CPF, Metadata, Geometric Grid, and LPGS-Generated Data 4–9

4.5.3 Error Margins, Overheads, and Reserves 4–10

4.5.4 Hardware Related Parameters 4–11

4.6 Benchmark Results for Geometric Processing 4–14

5. Model Results

5.1 Model Implementation 5–1

5.2 Description of Microsoft Excel Spreadsheet Model 5–1

5.3 Spreadsheet Model Results 5–1

5.3.1 Spreadsheet Model Results—Without Error Margins and Overheads 5–1

5.3.1.1 Data Process 5–2

5.3.1.2 Data Transfer 5–2

5.3.1.3 Data Storage 5–9

5.3.2 Spreadsheet Model Results—With Error Margins and Overheads 5–15

5.3.3 Spreadsheet Model Results—Total Service Time 5–19

5.3.4 Spreadsheet Model Results—Disk and Memory Requirements 5–19

6. Summary and Conclusions

6.1 Number of CPU Cycles for Average Instructions 6–1

6.2 Scene Size 6–1

6.2.1 Data Volume and File Size (actual scene size) 6–1

6.2.2 Instruction Count (actual scene size) 6–3

6.2.3 Memory Requirements (actual scene size) 6–4

6.2.4 Service Time 6–5

6.3 Different Workloads 6–5

6.3.1 Workload Related Assumptions and Resource Requirements 6–5

6.3.2 Disk Storage 6–7

6.3.3 Workload 1—25 WRS Scenes per Day 6–8

6.3.3.1 Service Time 6–8

6.3.3.2 System Throughput 6–8

6.3.3.3 Resource Utilization 6–11
6.3.3.4 Timing of Staging L0R Product for LPGS by ECS 6–13
6.3.4 Workload 2—50 WRS Scenes per Day 6–18
6.3.4.1 Service Time 6–18
6.3.4.2 System Throughput 6–18
6.3.4.3 Resource Utilization 6–21
6.3.5 Workload 3—75 WRS Scenes per Day 6–24
6.3.5.1 Service Time 6–24
6.3.5.2 System Throughput 6–24
6.3.5.3 Resource Utilization 6–27
6.3.6 Workload 4—100 WRS Scenes per Day 6–30
6.3.6.1 Service Time 6–30
6.3.6.2 System Throughput 6–30
6.3.6.3 Resource Utilization 6–33
6.3.3.4 Timing of Staging L0R Product for LPGS by ECS 6–35

Appendix A. Radiometric Processing Process Flow

Appendix B. QASE Simulation Model

Appendix C. Processing Scenarios

Acronyms and Abbreviations

List of Figures

4–1 LPGS Hardware Configuration 4–1

4–2 Modeled LPGS Hardware Configuration 4–2

4–3 LPGS Process Flow 4–2

4–4 Sample Worksheet for Instruction Count Estimate 4–6

6–1 CPU Utilization per Day As a Function of Scene Size and Number of CPU Cycles per Instruction (Nominal Processing Only) (workload = 25 + 3 scenes per day) 6–12

6–2 CPU Utilization per Day As a Function of Scene Size and Number of CPU Cycles per Instruction (Including Non-nominal Processing) (workload = 25 + 3 scenes per day) 6–13

6–3 CPU Utilization per Day As a Function of Scene Size and Number of CPU Cycles per Instruction (Nominal Processing Only) (workload = 50 + 5 scenes per day)..... 6–22

6–4 CPU Utilization per Day As a Function of Scene Size and Number of CPU Cycles per Instruction (Including Non-nominal Processing) (workload = 50 + 5 scenes per day) 6–23

6–5 CPU Utilization per Day As a Function of Scene Size and Number of CPU Cycles per Instruction (Nominal Processing Only) (workload = 75 + 8 scenes per day) 6–28

6–6 CPU Utilization per Day As a Function of Scene Size and Number of CPU Cycles per Instruction (Including Non-nominal Processing) (workload = 75 + 8 scenes per day) 6–29

6–7 CPU Utilization per Day As a Function of Scene Size and Number of CPU Cycles per Instruction (Nominal Processing Only) (workload = 100 + 10 scenes per day) 6–34

6–8 CPU Utilization per Day As a Function of Scene Size and Number of CPU Cycles per Instruction (Including Non-nominal Processing) (workload = 100 + 10 scenes per day) 6–35

List of Tables

4–1 Mapping of Processes/Functions to HWCIs 4–4

4–2 Parameters for Image Size 4–8

4–3 Parameters for File Size Estimates for MSCD, PCD, Metadata, CPF, Geometric Grid, and LPGS-Generated File 4–9

4–4 Error Margins, Overheads, and Reserves 4–11

4–5 Hardware Related Parameters 4–12

4–6 Benchmark Results for Origin 200 4–13

4–7 Benchmark Results for Geometric Processing 4–14

5–1 Instruction Count Summary for Radiometric Processing of One WRS Scene 5–3

5–2 Volume of Data Transferred via FDDI for One WRS Scene (Raw Data) 5–5

5–3 Data Volume Transferred via Disk for Nominal Processing of One WRS Scene (Raw Data) 5–6

5–4 Data Volume Transferred via Disk for Non-nominal Processing of One WRS Scene (Raw Data) 5–8

5–5 Memory Requirements per Band for Nominal Processing of One WRS Scene (Raw Data) 5–10

5–6 Memory Requirements per Band for Nominal Processing of Three WRS Scenes (Raw Data) 5–12

5–7 Disk Storage Requirements for Workload of 25 Scenes per Day (Raw Data) 5–14

5–8 Summary of Results (Raw Data Without Error Margins, Overheads) for L1 Processing HWCI 5–16

5–9 Summary of Results (Raw Data Without Error Margins, Overheads) for QA/AA HWCI 5–17

5–10 Summary of Results (Data With Error Margins, Overheads) for L1 Processing HWCI 5–18

5–11 Summary of Results (Data With Error Margins, Overheads) for QA/AA HWCI 5–19

5–12 Total Service Time for Processing One WRS Scene With One CPU 5–20

5–13 Time for Transferring One WRS Scene to the QA/AA HWCI for Non-nominal Processing 5–20

5–14 Memory and Disk Storage Requirements 5–20

6–1 Comparisons of Data Volumes and File Sizes for Different Scene Sizes (actual scene size) 6–2

6–2 Ratios of Data Volumes and File Sizes for Different Scene Sizes with Respect to a Full Scene (actual scene size) 6–2

6–3 Instruction Counts for Different Scene Sizes for Radiometric Processing (actual scene size) 6–3

6–4 Ratios of Instruction Counts with Respect to One Full Scene for Different Scene Sizes (actual scene size) 6–4

6–5 Comparisons of Memory Requirements for Different Scene Sizes (actual scene size) 6–5

6–6 Resource Requirements for Different Workloads 6–6

6–7 Workload Related Assumptions 6–6

6–8 Disk Storage for Different Workloads 6–7

6–9 Service Time for Different Scene Sizes (workload = 25 + 3 scenes/day) 6–9

6–10 Service Time for Different Scene Sizes as a Function of CPU Cycles per Instruction (workload = 25 + 3 scenes/day) 6–10

6–11 System Throughput Using Four CPUs (workload = 25 + 3 scenes/day) 6–11

6–12 Resource Utilization over a 24-Hour Period (workload = 25 + 3 scenes/day) 6–12

6–13 Average Idle Time (in hours) per Processor (best case) (for a duration equal to turnaround time) (workload = 25+ 3 scenes/day) 6–14

6–14 Percent System Idle Time (best case) (workload = 25+ 3 scenes/day) 6–15

6–15 Number of Scenes that can be Processed per Day (assuming 75 percent utilization) (best case) (workload = 25+ 3 scenes/day) 6–15

6–16 Total Idle Time (in processor-hours) (worst case) (for a duration equal to reference duration) (workload = 25+ 3 scenes/day) 6–17

6–17 Percent System Idle Time (worst case) (workload = 25+ 3 scenes/day) 6–17

6–18 Number of WRS Scenes that can be Processed per Day (worst case) (assuming 75 percent utilization) (workload = 25+ 3 scenes/day) 6–17

6–19 Service Time for Different Scene Sizes (workload = 50 + 5 scenes/day) 6–19

6–20 Service Time for Different Scene Sizes as a Function of CPU Cycles per Instruction (workload = 50 + 5 scenes/day) 6–20

6–21 System Throughput Using Eight CPUs (workload = 50 + 5 scenes/day) 6–21

6–22 Resource Utilization over a 24-Hour Period (workload = 50 + 5 scenes/day) 6–22

6–23 Service Time for Different Scene Sizes (workload = 75 + 8 scenes /day) 6–25

6–24 Service Time for Different Scene Sizes as a Function of CPU Cycles per Instruction (workload = 75 + 8 scenes/day) 6–26

6–25 System Throughput Using 12 CPUs (workload = 75 + 8 scenes/day) 6–27

6–26 Resource Utilization over a 24-Hour Period (workload = 75 + 8 scenes/day) 6–28

6–27 Service Time for Different Scene Sizes (workload = 100 + 10 scenes/day) 6–31

6–28 Service Time for Different Scene Sizes as a Function of CPU Cycles per Instruction (workload = 100 + 10 scenes/day) 6–32

6–29 System Throughput Using 16 CPUs (workload = 100 + 10 scenes/day) 6–33

6–30 Resource Utilization over a 24-Hour Period (workload = 100 + 10 scenes/day) 6–34

6–31 Average Idle Time (in hours) per Processor (best case) (for a duration equal to turnaround time) (workload = 100 + 10 scenes/day) 6–36

6–32 Percent System Idle Time (best case) (workload = 100 + 10 scenes/day) 6–37

6–33 Number of Scenes that can be Processed per Day (assuming 75 percent utilization) (best case) (workload = 100 + 10 scenes/day) 6–37

6–34 Total Idle Time (in processor-hours) (worst case) (for a duration equal to reference duration) (workload = 100 + 10 scenes/day) 6–39

6–35 Percent System Idle Time (worst case) (workload = 100 + 10 scenes/day) 6–39

6–36 Number of WRS Scenes that can be Processed per Day (worst case) (assuming 75 percent utilization) (workload = 100 + 10 scenes/day) 6–40

1. Introduction

1.1 Scope

This document contains the approaches, assumptions, and results of performance and sizing estimates for the Earth Science Data and Information System (ESDIS) Level 1 Product Generation System (LPGS).

1.2 LPGS Overview

The LPGS is a source of Enhanced Thematic Mapper Plus (ETM+) Level 1 (L1) data within the ESDIS Ground System (EGS). The EGS is a collection of ground support elements for the Earth Observing System (EOS) and includes the EOS Data and Information System (EOSDIS), institutional support elements, affiliated and international partner data centers, international partner instrument control and operations centers, and other sources of data. The LPGS is located at the Earth Resources Observation System (EROS) Data Center (EDC) Distributed Active Archive Center (DAAC) and provides ETM+ L1 digital image generation and transfer services on a demand basis. The LPGS receives L1 digital image generation requests and distributes generated L1 digital images to customers through the EOSDIS Core System (ECS) at the EDC DAAC nominally on a first in-first out (FIFO) basis .

The LPGS produces L1 data images in electronic format corresponding to a Worldwide Reference System (WRS) scene, floating scene center, or partial ETM+ subintervals of up to three WRS scene equivalents based on customer requests. The LPGS is capable of producing a daily volume equivalent to at least 25 WRS scenes of L1 radiometrically corrected and geometrically corrected images in any combination. The LPGS can create digital images projected to different coordinate reference systems, for any combination of the eight spectral channels collected by the ETM+ instrument, or in different output formats according to other options specified in the customer's request. The Level 0R (L0R) data are requested from the ECS, and appended calibration parameter, payload correction data (PCD), and mirror scan correction data (MSCD) files are applied by the LPGS in producing L1 d igital images.

The digital images created by the LPGS are provided, along with, quality information (metadata), associated calibration parameter file (CPF), PCD, MSCD, and calibration data to the ECS, which distributes the entire L1 product to the customer.

2. Documentation

2.1 Applicable Documents

The information in the following documents was used to conduct the performance and sizing estimates for the LPGS:

1. NASA GSFC, 510-FPD/0196, *Level 1 Product Generation System (LPGS) Functional and Performance Requirements Specification,* February 1997
2. NASA GSFC, 510-3OCD/0296, *Level 1 Product Generation System (LPGS) Operations Concept,* February 1997
3. NASA GSFC, 510-4SDS/0196, *Level 1 Product Generation System (LPGS) System Design Specification,* March 1997
4. NASA GSFC, 510-3DFC/0197, *Level 1 Product Generation System (LPGS) Output Files Data Format Control Book,* August 1997
5. NASA GSFC, 430-11-06-007-0, *Landsat 7 0R Distribution Product Data Format Control Book (DFCB), HDF Version,* February 1997
6. NASA GSFC, 430-15-01-002-0, *Landsat 7 Calibration Parameter File Definition,* February 1997
7. NASA GSFC, 23007702-IVC, *Landsat 7 System Data Format Control Book (DFCB), Volume IV—Wideband Data,* April 1996
8. NASA GSFC, *Landsat 7 Image Assessment System (IAS) System Design Specification,* February 1997
9. *Radiometry Algorithm Descriptions* on the Web at URL http://ltpwww.gsfc.nasa.gov/LANDSAT/
10. *Landsat 7 Image Assessment System (IAS) Geometric Algorithm Theoretical Basis Document* on the Web at URL http://edcwww.cr.usgs/IAS
11. Silicon Graphics, *Origin 2000TM Technical Description* on the Web at URL http://www.sgi.com/
12. Storey, J., February 18, 1997 memorandum to J. Henegar summarizing IAS benchmark sizing and analysis conducted at EDC
13. Davis, B., May 9, 1997 E-mail to W. Wang summarizing preliminary TMRESAMPLE timing information
14. *Benchmark Results* on the Web at URL http://performance.netlib.org/performance/html/PDStop.html

2.2 Reference Documents

The following document was used for background information.

EDC IAS Turnover Materials

3. LPGS Performance Requirements

The following are the performance requirements for the LPGS hardware, software, and workload scenarios:

Requirement 3.3.7.4 The LPGS shall be able to store Level 1 processing information on-line for 90 days.

Requirement 4.1.1 The LPGS shall be capable of processing a volume of data equivalent to 28 (accounts for 10 percent LPGS internal reprocessing) standard L0R WRS scenes to Level 1 digital images each day.

Requirement 4.1.4 The LPGS shall provide at least 110 percent of the processing throughput capability required to satisfy the worst-case processor loading.

Requirement 4.1.5 The LPGS shall provide at least 125 percent of the random access memory capacity required to satisfy the worst case memory loading.

Requirement 4.1.6 The LPGS shall provide at least 125 percent of the peripheral storage capacity required to satisfy the worst case peripheral storage loading.

Requirement 4.2.1 The LPGS shall be able to ingest from ECS a data volume equivalent to three WRS scenes worth of standard L0R data for each Level 1 digital image request.

Requirement 4.2.2 The LPGS shall have the capability to support the transfer to ECS of the equivalent of a minimum of 25 WRS sized Level 1 digital images per day .

Requirement 4.2.3 The LPGS-ECS interface shall provide the capability to transfer to the ECS at least 33 GB of Level 1 output files per day.

4. Modeling Approaches

This section details the approaches used to model the LPGS hardware, process flow, and workload.

4.1 Hardware Configuration

The LPGS hardware configuration is shown in Figure 4–1. A stripped-down version of the hardware configuration used for modeling is shown in Figure 4–2. Only the L1 processing hardware configuration item (HWCI) and quality assessment (QA)/anomaly analysis (AA) HWCI are considered for the modeling. The internal network HWCI, Operations Interface HWCI, and Printer HWCI are excluded for this modeling study. The L1 Processing HWCI is for the L1 product generation and storage. It is assumed that the visual assessment of data quality for the automatic QA will be done on the workstation in this HWCI. For the non-nominal processing (anomaly analysis), processing of data will be done on the L1 Processing HWCI but the manual analysis and visual assessment of the images (for both benchmark work order and diagnostic work order) will be done on the QA/AA HWCI.

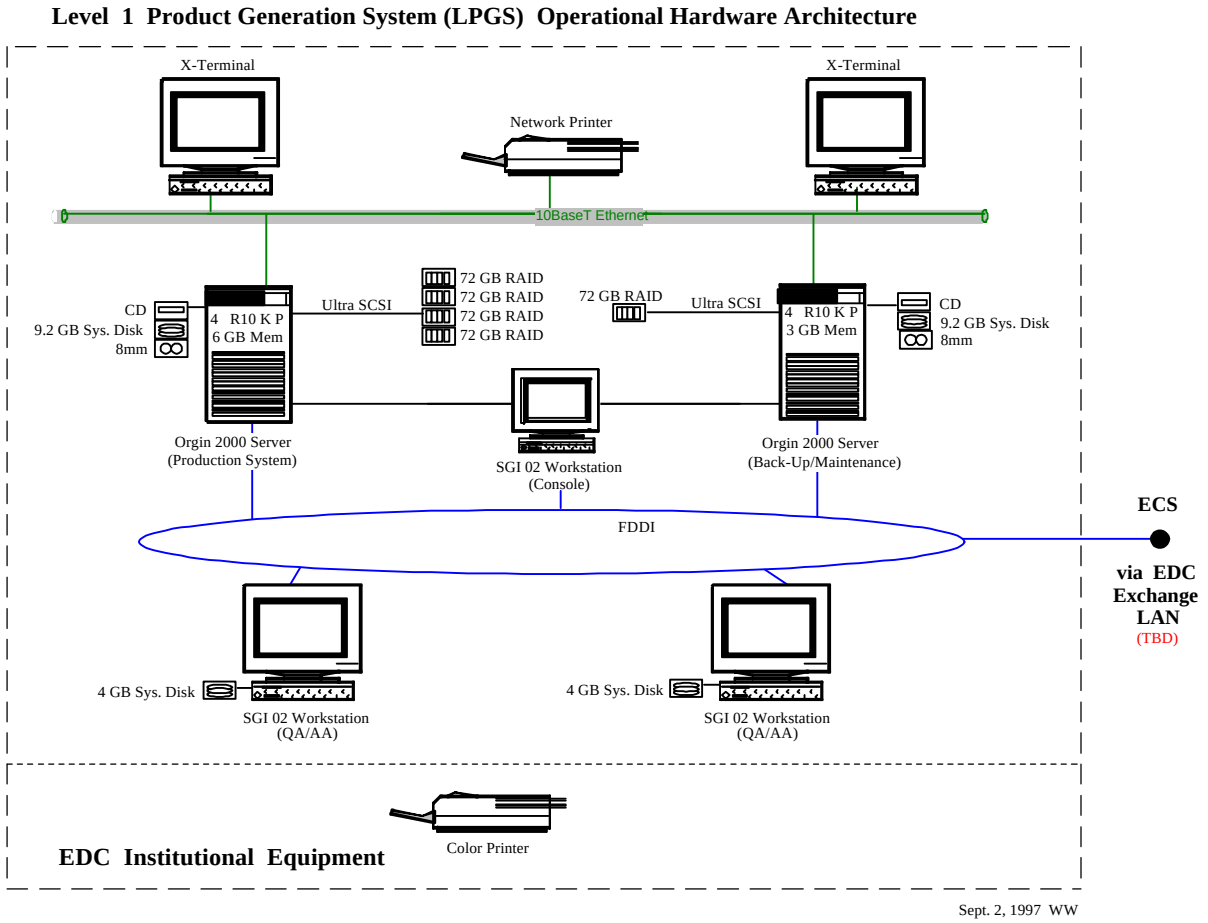


Figure 4–1. LPGS Hardware Configuration

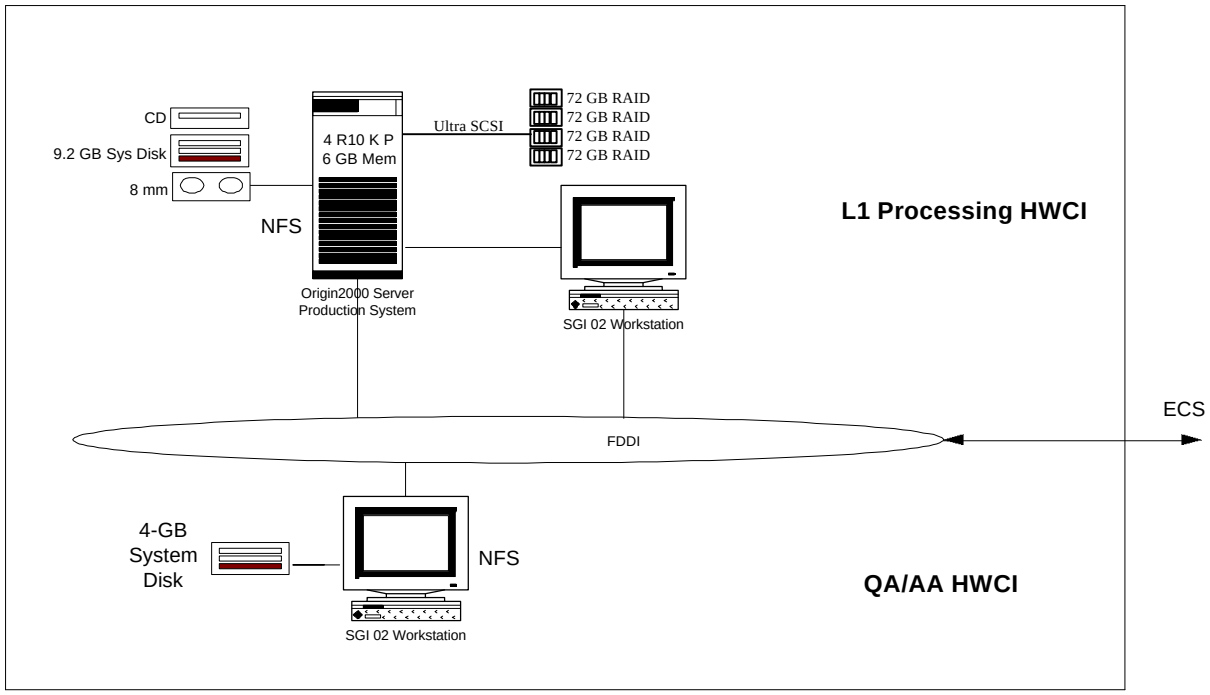


Figure 4–2. Modeled LPGS Hardware Configuration

4.2 Process Flow

The process flow for processing L1 products from ingest to ECS notification and product transfer is shown in Figure 4–3.

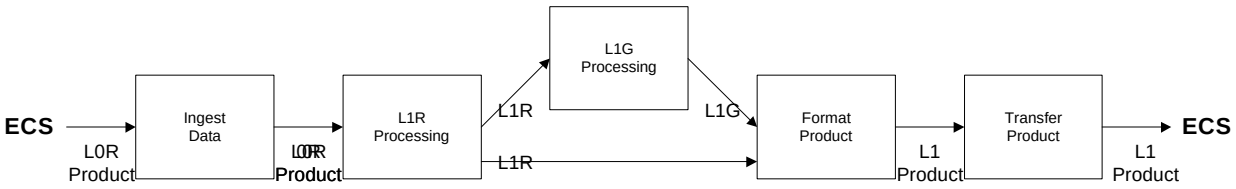


Figure 4–3. LPGS Process Flow

The major functions for each process are described below:

- Ingest data
    - Retrieve L0R product to the input directory
- Level 1 radiometrically corrected (L1R) processing
    - 0R radiometric characterization
    - 0R correction
    - Corrected 0R (0Rc) radiometric characterization/calibration
    - 1R correction
    - 1R radiometric characterization/correction
    - Quality assurance of L1R image
- Level 1 geometrically corrected (L1G) processing
    - Create extended image
    - Resample
    - Quality assurance of L1G image
- Format product
    - Convert L1 product into appropriate format
    - Package L1 product
    - Move L1 product to the output directory
    - Quality assurance of L1 image
- Transfer Product
    - Notify ECS of L1 product availability
    - Retrieve L1 product from the LPGS output directory (ECS performs)

The detail process flow diagrams for the L1R processing are shown in Appendix A.

4.3 Mapping of Processes/Functions to HWCI

Two operational scenarios are considered in the model: the nominal processing and the non-nominal processing (anomaly analysis). The nominal processing scenario consists of processing a work order from ingest through product transfer following the process flow shown in Figure 4–3. The non-nominal processing consists of processing up to three different work orders: benchmark work order, diagnostic processing work order, and reprocessing work order. For modeling purposes, the processing of reprocessing work orders will be treated the same as the processing of normal work orders.

Table 4–1 shows the mapping between the processes/functions identified in Section 4.2 and the HWCIs identified in Section 4.1 for these two scenarios.

Table 4–1. Mapping of Processes/Functions to HWCIs

Process/Function	Nominal Processing	Non-nominal Processing		
		Benchmark Work Order	Diagnostic Work Order	Reprocessing Work Order
Ingest Data				
Retrieve L0R product to the input directory	L1 Proc HWCI via FDDI	n/a	n/a	n/a
L1R Processing				
0R radiometric characterization	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
0R correction	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
0Rc radiometric characterization/ calibration	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
1R correction	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
1R radiometric characterization/ correction	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
Quality assurance of L1R image	L1 Proc HWCI	QA/AA HWCI	QA/AA HWCI	L1 Proc HWCI
L1G Processing				
Create extended image	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
Resample	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
Quality assurance of L1G image	L1 Proc HWCI	QA/AA HWCI	QA/AA HWCI	L1 Proc HWCI
Format Product				
Convert L1 product into appropriate format	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
Package L1 product	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
Move L1 product to the output directory	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
Quality assurance of the L1 image	L1 Proc HWCI	QA/AA HWCI	QA/AA HWCI	L1 Proc HWCI
Transfer Product				
Notify ECS of L1 product availability	L1 Proc HWCI via FDDI	n/a	n/a	L1 Proc HWCI via FDDI
Retrieve L1 product from the output directory by ECS.	L1 Proc HWCI via FDDI	n/a	n/a	L1 Proc HWCI via FDDI

Note: For the diagnostic processing work order, processing of data will be done on the L1 Processing HWCI but the results will be displayed and analyzed on the QA/AA HWCI.

4.4 Approaches

To estimate the total service time for the L1 product generation from ingest to product transfer, it is necessary to estimate the amount of time it takes to process the data as well as the amount of time it takes to transfer the data through various media, including the fiber-optic data distribution interface (FDDI) and disk. The approaches used for estimates are described below.

4.4.1 Data Process

Wherever the benchmark or prototype results are available, the benchmark results are used to extrapolate the processing time for the related functions. Otherwise, the number of instructions required to perform each function is estimated based on the analysis of the available design or algorithms. The processing time is then obtained by multiplying the instruction count with the processing speed of average instructions.

Some prototype results are available for the geometric processing. Therefore the processing time for the geometric processing is extrapolated from these results.

For the radiometric processing, only results for the memory effect correction are available. Therefore, a detailed analysis of the applicable algorithms is performed to estimate the required instruction count for each function. For each function, the analysis includes reviewing the applicable algorithms or prototype code, estimating the number of loops involved, and estimating the number of operations involved within each loop. The total number of instructions is then calculated for each function. These instruction counts are then grouped by steps corresponding to the steps of the radiometric processing flow shown in Appendix A.

The prototype results for the memory effect correction are then used to sanity-check the assumption for the processing speed.

A sample worksheet used for this analysis is shown in Figure 4–4.

4.4.2 Data Transfer

Data transfer needs are identified for each of the major functions in the process flow. The volumes of the data to be transferred through various media for each of the major functions are estimated. Media such as the FDDI and disk are considered.

4.4.3 Data Storage

Data storage needs are estimated for the disk and memory for both the L1 Processing HWCI and QA/AA HWCI. The storage requirement for the disk is estimated for input, processing, output, anomaly analysis and database. The memory required is estimated for each of the major functions. The overall memory requirement is obtained by taking the maximum memory requirement among all functions.

4.1.2 Correct Memory Effect (new from Dennis Helder)

Parameters & Assumptions	**Bands 1-5 & 7**	**Band 6 (Lo & Hi)**	**Band 8**
No. of Bands requiring ME correction	6	1	1
# of filter intervals	3000	3000	6000
# of filter step widths (steps)	7	7	14

```
Input
                    Scene (0R)
                    IC (0R)
                    Memory Effect magnitude and time constant for each detector
Output
                    ME corrected image and IC data
Process:
1
1.1                     for each band
1.2                       for each detector
                            (Create a vector of filter coefficients for the given
                            detector) (not a function of image)
1.3                         for each interval of filter
                              compute coefficient
                            end for interval
                            (Convolution)
                            (For loop to determine the output of the first specified number (=# of intervals) of
                            minor frames (3000))
1.4                         for each interval
                              for each step
1.6                             for each interval (yes, another loop of intervals) (combination of steps and filter step
                                width)
                                  Compute sum of data under step (5 integer Ops, 3 FP
                                  Ops)
                                end for interval
1.6a                            Add result to output for this interval (8 integer Ops, 4 FP
                                Ops)
                              end for step
                            end for interval
                            (Second loop )
1.7                         for each scan
1.8                           for each pixel
1.9                             for each step
                                  Compute new output (10 integer Ops, 8 FP Ops)
                                end for step
                              end for pixel
                            for each scan
                          end for detector
                        end for band
```

Figure 4–4. Sample Worksheet for Instruction Count Estimate (1 of 2)

	Basis	Frequency	Band 1-5&7 No. of Occurrences	Band 6 No. of Occurrences	No. of Occurrences	No. of Integer Ops	No. of FP Ops	Total Integer Ops (Mega)	Total FP Ops (Mega)
1.1	by band	1	6	1	1				
1.2	by detector	1	16	8	32				
1.3	by interval	1	3000	3000	6000				
	overall	1	288000	24000	192000	2	100	1.008	50.400
1.1	by band	1	6	1	1				
1.2	by detector	1	16	8	32				
1.4	by filter interval	1	3000	3000	6000				
1.6 (except 1.6a)	by filter interval	1	3000	3000	6000				
	overall	1	864000000	72000000	1152000000	7	3	14616.000	6263.994
1.1	by band	1	6	1	1				
1.2	by detector	1	16	8	32				
1.4	by filter interval	1	3000	3000	6000				
1.5, 1.6a	by step	1	7	7	14				
	overall	1	2016000	168000	2688000	10	4	48.720	19.488
Scene Data									
1.1	by band	1	6	1	1				
1.2	by detector	1	16	8	32				
1.7	by scan	1	374	374	374				
1.8	by pixel	1	6600	3300	13200				
1.9	by step	1	7	7	14				
	overall	1	1658764800	69115200	2211686400	12	8	47274.797	31516.500
IC Data									
1.1	by band	1	6	1	1				
1.2	by detector	1	16	8	32				
1.7	by scan	1	374	374	374				
1.8	by pixel	1	1160	580	2320				
1.9	by step	1	7	7	14				
	overall	1	291540480	12147520	388720640	12	8	8308.904	5539.264
Misc.	by band	1	6	1	1		10000	0.000	0.080
Total								70249.428	43389.725

Figure 4–4. Sample Worksheet for Instruction Count Estimate (2 of 2)

4.5 Parameters and Assumptions

This section describes the parameters and assumptions used globally in the model. These include parameters used for file size estimate, image size estimate, and hardware characteristics.

4.5.1 Image-Related Parameters

Table 4–2 summarizes the parameters/values pertaining to the images. Some of these parameters are also used for the estimation of loop counts in the instruction count estimation. Parameters are shown in ***Bold Italic*** and the derived values are shown in regular font. The sources of data are shown in the Note column.

Table 4–2. Parameters for Image Size

		Scene Size =		**1**	**WRS Scene(s)**			
Scene size		***1***						
L1G File Size Flag		***average***	(average=worst case average, actual=actual size)					
Major Frame Period (ETM+ Scan Time)		***71.34***	ms					
		3						
Number of Scans/WRS Scene		***374***	scans					
# of scan lines in input buffer for L1G		***50***	lines					
	Unit	**Bands**	**Band 6**	**Band 8**	**Format**	**Product**	**Complete**	**Note**
		1-5 & 7	**(Lo & Hi)**		**1/2**		**Scene**	
Total Number of Bands/Formats		***6***	***1***	***1***	***2***			
0R Scene Data								
Pixels/Scan Line	Pixel	***6600***	***3300***	***13200***				Landsat 7 0R DFCB (sec. 4.0)
Scan Lines/Scan		***16***	***8***	***32***				Landsat 7 0R DFCB (sec. 4.0)
Number of Scans/Band/Scene		***374***	***374***	***374***				Landsat 7 0R DFCB (sec. 3.1)
Pixels/Band/Scene	Pixel	39494400	9873600	157977600				
Pixels/Scene	Pixel	236966400	9873600	157977600			**404,830,000**	
L1G Scene Data								
Pixels/Scan Line	Pixel	***6600***	***3300***	***13200***				
Scan Lines/Scan		***16***	***8***	***32***				
Number of Scans/Band/Scene		***374***	***374***	***374***				
Pixels/Band/# of Scenes (worst case average)	Pixel	100466784	25116696	401867136				
Pixels/Band/for actual # of Scenes	Pixel	79178528	19794632	316714112				
Pixels/Band (one of two above) (depending on the L1G file size flag)	Pixel	100466784	25116696	401867136				
Pixels/# of Scenes (based on flag)	Pixel	602800704	25116696	401867136			**1,029,800,000**	
Internal Calibration Data								
Pixel/Scan Line	Pixel	***1160***	***580***	***2320***				Landsat 7 0R DFCB (Table 5.1)
Scan Lines/Scan		***16***	***8***	***32***				Landsat 7 0R DFCB (sec. 4.0)
Number of Scans/Band/Scene		***374***	***374***	***374***				Landsat 7 0R DFCB (sec. 3.1)
Pixels/Band/Scene	Pixel	6941440	1735360	27765760				
Pixels/Scene	Pixel	41648640	1735360	27765760			**71,160,000**	

4.5.2 MSCD, PCD, CPF, Metadata, Geometric Grid, and LPGS-Generated Data

Table 4–3 summarizes the parameters/values used to estimate the file size for MSCD, PCD, CPF, metadata, geometric grid, and LPGS-generated process-related file and trending data. Parameters are shown in ***Bold Italic*** and the derived values are shown in regular font. The sources of data are shown in the Note column.

Table 4–3. Parameters for File Size Estimates for MSCD, PCD, Metadata, CPF, Geometric Grid, and LPGS-Generated File (1 of 2)

	Scene Size =		**1**	**WRS Scene(s)**				
Scene size		***1***						
Major Frame Period (ETM+ Scan Time)	***71.343***	ms						
Number of Scans/WRS Scene	***374***	scans						
	Unit	**Bands 1-5 & 7**	**Band 6 (Lo & Hi)**	**Band 8**	**Format 1/2**	**Product**	**Complete Scene**	**Note**
Total Number of Bands/Formats		***6***	***1***	***1***	***2***			
MSCD Data								
Bytes/Record	Byte				***79***			Landsat 7 0R DFCB (Table 5.2)
Number of Records/Scan					***1***			Landsat 7 0R DFCB (Table 5.2)
Number of Scans/Format/Scene					***374***			Landsat 7 0R DFCB (sec. 3.1)
Bytes/Format/Scene	Byte				29546			
Bytes/Scene	Byte				59092		**60,000**	
PCD Data								
Bytes/Record	Byte				***26472***			Landsat 7 0R DFCB (Table 5.3)
Number of records for 14 min. interval/Format					***206***			Landsat 7 0R DFCB (Table 5.3)
Bytes/14 min./Format	Byte				5453232			Assume worst case of 14 min. w/o subsetting
Bytes/14 min.	Byte				10906464		**10,910,000**	
LPS Meta Data (ASCII Text)								
Bytes/Record	Byte				***80***			Assume one text line per record
Number of Records for Header					***60***			Landsat 7 0R DFCB (Table 5.4)
Number of Records/ Scene/Format					***91***			Landsat 7 0R DFCB (Table 5.4)
Number of Scenes/Format					***2***			Assume not starting at WRS scene boundary
Number of Record/Format					***242***			
Factor to include comments					***2***			Assumption
Bytes/Format/Scene	Byte				38720			
Bytes/Scene	Byte				77440		**80,000**	
ECS Meta Data (ASCII Text)								
Bytes/Record	Byte					***80***		Assume one text line per record
Number of Records/Product						***49***		Landsat 7 0R DFCB (Table 5.5)
Factor to include comments						***2***		Assumption
Bytes/Scene	Byte					7840	**10,000**	
Calibration Parameter File (ASCII Text)								
Bytes/Record	Byte					***80***		Assume one text line per record
Number of Records/Product						***1243***		Landsat 7 CPF Definition, assume 11 records per page, 113 pages
Factor To Include Comments						***2***		Assumption
Bytes/Scene	Byte					198880	**200,000**	
Total for MSCD/PCD/Meta Data/CPF							**11,060,000**	

Table 4–3. Parameters for File Size Estimates for MSCD, PCD, Metadata, CPF, Geometric Grid, and LPGS-Generated File (2 of 2)

	Scene Size =		**1**	**WRS Scene(s)**				
Scene size	***1***							
Major Frame Period (ETM+ Scan Time)	***71.343*** ms							
Number of Scans/WRS Scene	***374*** scans							
	Unit	**Bands**	**Band 6**	**Band 8**	**Format**	**Product**	**Complete Scene**	**Note**
		1-5 & 7	**(Lo & Hi)**		**1/2**			
Total Number of Bands/Formats		***6***	***1***	***1***	***2***			
LPGS Process Data (accounting, status, characterization results etc.)								
Bytes/Band/1 WRS scene	Bytes	***1500000***	***1500000***	***4000004***				
Bytes/Band/Scene	Bytes	1500000	1500000	4000000				
Bytes/Scene	Bytes	9000000	1500000	4000000				
Total for LPGS Process Data (accounting, status, characterization results etc.)							**14,500,000**	
Geometric Grid								
Bytes/Band	Bytes	***4000000***	***2000000***	***800000***				
Bytes/Total (scene independent)	Bytes	24000000	2000000	8000000				
Total for Geometric Grid							**34,000,000**	
Trending Data								
Trending Data/Scenes	Bytes					150000	150000	
Total for Trending Data							**150,000**	

4.5.3 Error Margins, Overheads, and Reserves

Table 4-4 summarizes the parameters/values used for error margins, overheads, and reserves. The parameters are shown in ***Bold Italic*** and the derived values are shown in regular font.

- Error margins

  These values account for the estimation inaccuracies and are expressed in percentages.

- Operating system and program overheads

  These values account for the additional space needed for the operating system and programs.

- Additional requirements per functional and performance requirements specification (F&PRS)

  As imposed by the LPGS performance requirements 4.1.4 and 4.1.5, the LPGS shall provide at least 125 percent of storage and memory capacity required to satisfy the worst-case loading. These values are used to account for these requirements and are expressed in percentages.

Table 4–4. Error Margins, Overheads, and Reserves

Parameter	Value
Error Margin	
Processing	***50%***
Benchmark	***0%***
Memory	***0%***
Disk I/O	***10%***
FDDI I/O	***10%***
Disk Storage	***0%***
O/S & Program O/H	
Processing	***0***
Benchmark	***0***
Memory (per processor)	***40*** MB per processor
Disk I/O	***0***
FDDI I/O	***0***
Disk Storage	***0*** GB (Assuming system disk not in RAID)
Memory (entire system)	***512*** MB for entire system
Additional Requirement per F&PRS	
Processing	***0%***
Benchmark	***0%***
Total Processing Time	***0%***
Memory	***25%***
Disk I/O	***0%***
FDDI I/O	***0%***
Disk Storage	***25%***

4.5.4 Hardware Related Parameters

Table 4-5 summarizes the parameters/values pertaining to the hardware configuration. The parameters are shown in ***Bold Italic*** and the derived values are shown in regular font. These parameters are further discussed below:

Table 4–5. Hardware Related Parameters

Parameter	Value
CPU Processing Time	
Origin 2000 CPU speed	***195*** MHz
# of cycles/average instruction	***2.0*** cycles/instruction
Origin 2000 Processing Time	0.01026 micro seconds/ops
W/S O2 CPU speed	***150*** MHz
FDDI transfer rate	***60*** Mbps
RAID transfer rate (up to four RAIDs in a stripped configuration)	***70*** MBPS
W/S Disk transfer rate	***20*** MBPS
CPU overhead during FDDI data transfer	***20%***
Origin 2000 CPU O/H associated with FDDI data transfer	0.0267 sec/MB
W/S O2 CPU O/H associated with FDDI data transfer	0.0267 sec/MB
Number of CPU cycles for transferring 1 byte of data	***2*** cycles/byte (Assuming it takes 2 cycles of CPU to transfer 1 byte of data)
Origin 2000 CPU O/H associated with disk data transfer	0.01026 sec/MB
W/S O2 CPU O/H associated with disk data transfer	0.01333 sec/MB
Origin 2000 CPU degradation factor for 4-7 CPUs	***7%***
Origin 2000 CPU degradation factor for 8-11 CPUs	***10%***
Origin 2000 CPU degradation factor for 12-15 CPUs	***12%***
Origin 2000 CPU degradation factor for 16 CPUs	***14%***

- Central processing unit (CPU) speed

  The CPU of the Origin 2000 system is a 195-MHz processor while the CPU of the O2 workstation is a 150-MHz processor.

- Number of CPU cycles for average instruction

  The Origin 2000 is rated as a 390-Million Floating Point Operations (MFLOPS) (peak, or 0.5 cycles per instruction) processor since it can execute two floating point operations in one CPU cycle. This is because an instruction called “multiply-add” which consists of two operations—multiplication and addition—can be executed in one CPU cycle. However, most of the instructions take one or more cycles. Instructions such as floating point addition, subtraction, and multiplication take one cycle and floating point division takes 14 cycles. The 390 MFLOPS is the theoretical best performance of the Origin 2000. The real performance depends on the application and the way the software is implemented. The Linpack benchmark result for a single CPU is 344 MFLOPS.

Benchmark results that are obtained from the Netlib Repository Database (http://performance.netlib.org/) show that the Origin 200 can achieve 80 to 27 MFLOPS depending on the instruction mix (see Table 4–6). The Origin 200 also uses the same MIPS R10000 processors as Origin 2000 but is slightly slower (180 MHz). It can be extrapolated that the Origin 2000 can achieve 90 to 300 MFLOPS with the same instruction mix. The radiometric algorithms include a significant number of divisions, square root operations, which require many cycles to execute. Therefore the instruction mix might be closer to the instruction mix used in Benchmark 1 or 2 of Table 4–6.

Table 4–6. Benchmark Results for Origin 200

	Floating Point Addition	Floating Point Subtraction	Floating Point Multiplication	Floating Point Division	Origin 200 MFLOPS
Benchmark 1	40.4%	23.1%	26.9%	9.6%	84.346
Benchmark 2	38.2%	9.2%	43.4%	9.2%	79.996
Benchmark 3	42.9%	3.0%	50.7%	3.4%	154.366
Benchmark 4	42.9%	2.2%	54.9%	0.0%	269.263

The Silicon Graphics, Inc. (SGI) engineer has indicated that a program not properly implemented for parallel processing can be improved from 40 MFLOPS initially to about 100 MFLOPS after performance tuning and proper adjustment. Therefore two cycles per average instruction is used in computing the processing time required for the radiometric processing in this analysis. This is equivalent to 97.5 MFLOPS. This optimistic estimate may not be achieved at the initial implementation. (However, based on the Linpack benchmark results, 97.5 MFLOPS may be too conservative.)

The benchmark results obtained from the memory effect correction prototype are used as another data point for choosing two cycles per average instruction. The scientist has indicated that the processing time for the memory effect correction is about 2 minutes for a single band of Bands 1–5 using DEC Alpha 600 5/266. (The speed of the Origin 2000 is about 20 to 60 percent faster than DEC Alpha 600 based on the SPECint95 and SPECfp95.) This is equivalent to a processing time of 28 minutes to correct the memory effect for all bands. If two cycles per instructions is used, the processing time for the memory effect correction for all bands based on the instruction count estimate is about 29 minutes. This number is very close to the processing time extrapolated from the benchmark results.

Two cycles per instruction is equivalent to 0.01025 microseconds per instruction.

- FDDI transfer rate

  The FDDI transfer rate is assumed to be 60 megabits per second.

- Aggregate disk transfer rate

The aggregate disk transfer rate [redundant arrays of independent disks (RAID), small computer system interface (SCSI)] is assumed to be 70 megabytes per second (MBPS) with up to four RAIDs in a stripped configuration.

- Workstation disk transfer rate

  The disk transfer rate for the O2 workstation is assumed to be 20 MBPS.

- CPU overhead during FDDI data transfer

  It is assumed that 20 percent of one CPU time will be required during FDDI data transfer.

- Number of CPU cycles for transferring 1 byte of data

  It is assumed that two CPU cycles will be required to transfer 1 byte of data to or from the disk.

- CPU degradation factor for multiple CPUs

  It is assumed that the CPU performance will be slightly degraded for multiple CPUs. The SGI engineer has indicated that the degradation factor is about six percent for four CPUs and increases to 12 percent for 16 CPUs. Slightly conservative numbers of seven percent and 14 percent are used for four-CPU configuration and 16-CPU configuration respectively.

4.6 Benchmark Results for Geometric Processing

Preliminary benchmark results for the Image Assessment System (IAS) executed on an SGI Origin 2000 provided the basis for the LPGS geometric CPU loads. The data are summarized in Table 4–7.

The processing time for each of Bands 1 through 5 and Band 7 is about 180 seconds total with four CPUs. In this study, the CPU processing time is estimated based on one CPU, and a degradation factor is applied to derive the processing time for multiple CPUs. With a four-CPU configuration, the degradation factor to be used is 7 percent. This leads to an estimate of 167.40 seconds for Bands 1 through 5 and Band 7 with one CPU. Band 6 requires 75 percent of the amount of processing, or 125.55 seconds. Band 8 requires four times the amount of processing, or 669.60 seconds.

Table 4–7. Benchmark Results for Geometric Processing

Number of CPUs	CPU Time (sec)
1	143
2	78
3	57
4	45
5	37

6	33
7	29
8	27

5. Model Results

5.1 Model Implementation

Two performance models were developed: a Microsoft Excel spreadsheet model and a discrete-event/analytical model using Quantitative Case for Reliability and Timing (QASE RT). This section describes the spreadsheet model and discusses the results obtained from the spreadsheet model. The discussion is based on one WRS scene using the worst case situation. The discrete event model using QASE is discussed in the Appendix B.

5.2 Description of Microsoft Excel Spreadsheet Model

A Microsoft Excel spreadsheet model was developed to estimate the instruction counts, processing time, data volume, data transfer time, and data storage. The model consists of three spreadsheet files: "PROCESS," "DATA," and "SUM."

The PROCESS spreadsheet file details high-level processes for each function in the radiometric processing, the number of loops involved, and the number of instructions for each loop. The total instruction count for each function is then calculated. This spreadsheet generates the raw data for the SUM file and QASE model.

The DATA spreadsheet file details the amount of data transfer and amount of data storage required at each step of the process flow. This spreadsheet consists of several sections such as FDDI, disk input/output (I/O), memory, and disk storage. This spreadsheet generates the raw data for the SUM file and QASE model.

The SUM spreadsheet file is linked to the PROCESS and DATA files and uses the raw data generated from PROCESS and DATA files for summarization. Error margins, operating system overheads, and additional reserves are added to the raw data in this spreadsheet.

5.3 Spreadsheet Model Results

5.3.1 Spreadsheet Model Results—Without Error Margins and Overheads

The data presented below are considered as the raw data. These data are estimated using spreadsheet files PROCESS and DATA. These data do not include error margins, operating system overheads, and additional reserves required by the F&PRS. These raw data are used for the spreadsheet SUM as well as the QASE model and include the following:

- Level 1 Processing HWCI
  - Number of instructions estimated for each major step of the radiometric processing (from PROCESS)
  - Processing time estimated from benchmark results for the geometric processing (treated as parameters)
  - Memory storage estimated for each major step of the LPGS process flow (from DATA)
  - Amount of data transfer estimated for the disk I/O (from DATA)

    - Amount of data transfer estimated for the FDDI (from DATA)
    - Disk storage (from DATA)
- QA/AA HWCI
    - Amount of data transfer estimated for the disk I/O (from DATA)
    - Amount of data transfer estimated for the FDDI (from DATA)

5.3.1.1 Data Process

The number of instructions is estimated using the spreadsheet file PROCESS. The estimated instruction counts for all functions in the radiometric processing of one WRS scene are summarized in Table 5–1. Parameters used locally by each function are also indicated. The results indicate that 62.45 percent and 15.48 percent of the radiometric processing are for the memory effect correction and banding correction, respectively. The remaining functions contribute a total of 22.07 percent of the total instruction count of the radiometric processing.

5.3.1.2 Data Transfer

The data volumes transferred are estimated using the spreadsheet file DATA. The estimated data volumes transferred for one WRS scene through the FDDI are shown in Table 5–2. The estimated data volumes transferred for one WRS scene through the disk are shown in Table 5–3 for the nominal processing and in Table 5–4 for the non-nominal processing. The data volumes are estimated based on types of data being transferred for each of the major functions. The data volumes for most of data types including ICs, L0R images, and L1R images are linearly proportional to the image size. However, the data volumes for L1G images increase non-linearly as the size of the image increases. To consider the worst case, the data volume for a one-scene L1G image is assumed to be one-third of the data volume for a three-scene image. The Level 1 product could be either a L1G product or a L1R product depending on the user's request. The data volume for a L1G image is much higher than the data volume for the L1R image (for the worst case). The data volume for the L1G product is used in the calculation for L1 products.

For the non-nominal processing, the data volumes transferred are estimated assuming that all bands for all image files including intermediate files are to be read for assessment by the analyst. In reality, the analyst may only be interested in certain bands or certain files. The actual amount of data to be transferred could be significantly less.

Table 5–1. Instruction Count Summary for Radiometric Processing of One WRS Scene (1 of 2)

Process Specific Parameters/Ops		Freq. of Proc	Bands 1–5 and 7	Band 6 (Low and High)	Band 8	Total Int. Ops (Million)	Total FP Ops (Million)	Total Ops (Million) (X frequency)	% with respect to Total
2.1 Characterize Impulse Noise		1				441.129	853.876	1295.005	0.71%
% of pixels with impulse noise	1%								
2.3 Locate Scan-Correlated Shift (SCS)		1				4574.991	2.474	4577.465	2.52%
% of scan lines with SCS state transition	30%								
# of detectors used to determine SCS levels			3	3	3				
2.5 Characterize Dropped Lines		1				857.657	0.080	857.737	0.47%
% of scan lines with filled data	30%								
# of dropped lines/scan line	2								
# of dropped lines for scene			21542.4	1795.2	7180.8				
# of dropped lines for IC			21542.4	1795.2	7180.8				
2.6a Characterize Detector Saturation (A/D)		1				2927.199	0.080	2927.279	1.61%
% of A/D saturated pixel	1%								
2.6b Characterize Detector Saturation (Analog)		1				961.454	1965.823	2927.277	1.61%
% of analog saturated pixel	1%								
2.10a Histogram Analysis (Integer Operations)		1				3242.023	0.284	3242.307	1.78%
% of detectors w/o impulse noise and dropped lines	100 %								
# of bins per detector			256	256	256				
2.10b Histogram Analysis (Floating Point Operations)		2				810.451	2469.987	6560.877	3.61%
% of detectors w/o impulse noise and dropped lines	100 %								
# of bins per detector			3000	3000	3000				
3.4.1 Process IC Data - Emissive Band		1				640.653	2318.120	2958.773	1.63%
% of pixels in IC associated with dark current region	50%								
# of pixels in the dark current area			580	290	1160				
% of pixels in IC associated with shutter data	50%								
# of pixels in the shutter area			580	290	1160				
3.4.2 Process IC Data - Reflective Band		1				313.535	2282.183	2595.719	1.43%
% of pixels in IC associated with shutter data	50%								
% scan with scans with ghost pulse	30%								
# of pixels in the shutter area			580	290	1160				
# of lamp state per detector			2	2	2				
# of bands used for lamp state determination			2	2	2				

Table 5–1. Instruction Count Summary for Radiometric Processing of One WRS Scene (2 of 2)

Process Specific Parameters/Ops		Freq. of Proc	Bands 1–5 and 7	Band 6 (Low and High)	Band 8	Total Int. Ops (Million)	Total FP Ops (Million)	Total Ops (Million) (X frequency)	% with respect to Total
4.1.1 Combine Image and IC		1				1903.869	0.040	1903.909	1.05%
% of line in forward scan	50%								
% of line in reverse scan	50%								
4.1.2 Correct Memory Effect (new from Dennis Helder)		1				70249.428	43389.725	113639.153	62.45%
No. of Bands requiring memory effect correction			6	1	1				
# of filter intervals			3000	3000	6000				
# of filter step widths (steps)			7	7	14				
4.1.3 Apply Scan-Correlated Shift (SCS)		1				952.036	762.644	1714.681	0.94%
% of lines need SCS correction	30%								
% of lines do not need SCS correction	70%								
4.1.4 Apply Coherent Noise Correction		1				951.935	1428.021	2379.955	1.31%
% of scan lines with filled data	30%								
4.1.6 Separate Image and IC		1				951.935	951.974	1903.908	1.05%
% of line in forward scan	50%								
% of line in reverse scan	50%								
4.2 Apply Radiometric Correction		1				809.635	2024.166	2833.801	1.56%
4.3.1 Correct Dropped Lines		1				145.795	516.253	662.049	0.36%
% of scan lines with filled data	30%								
# of dropped lines/scan line	2								
# of dropped lines for scene			3590.4	1795.2	7180.8				
% of pixels with filled data/line	60%								
# of pixels/dropped line			1980	990	3960				
Dropped line correction method (Fill, Inline, Interpolate)	Interpolate								
4.3.2 Correct Inoperable Detectors		1				0.086	0.351	0.437	0.00%
# of inoperable detectors			2	1	2				
Inoperable detector correction method (Fill, Interpolate)	Interpolate								
4.3.4 Correct Stripping		1				809.635	0.216	809.851	0.45%
4.3.5 Correct Banding		1				7529.607	20645.757	28175.364	15.48%
% of scan lines with banding	30%								
6.5 Gain Switch and Apply Relative Gain Correction		1				0.000	0.107	0.107	0.00%
TOTAL						99073.055	79612.162	181965.656	100.00%
Total (excluding memory effect correction)						28823.627	36222.437	68326.502	
Total (excluding memory effect and banding)						21294.019	15576.680	40151.138	

Table 5–2. Volume of Data Transferred via FDDI for One WRS Scene (Raw Data)

FDDI Data Transfer for 1 WRS Scene for Nominal Processing										
	Type	**Bands 1-5 & 7 (M Pixels)**	**Band 6 (Lo & Hi) (M Pixels)**	**Band 8 (M Pixels)**	**Bytes/ pixel**	**Bands 1-5 & 7 (M Bytes)**	**Band 6 (Lo & Hi) (M Bytes)**	**Band 8 (M Bytes)**	**Band Independent (M Bytes)**	**Total for 1 WRS Scene (M Bytes)**
Ingest Data										
Write 0R Data to disk	byte	39.50	9.88	157.98	1	39.50	9.88	157.98		404.86
Write IC Data (0R) to disk	byte	6.95	1.74	27.77	1	6.95	1.74	27.77		71.21
Write MSCD/PCD/Meta/CPF to disk	byte								11.06	11.06
Total for Ingestion						**46.5**	**11.6**	**185.8**	**11.1**	**487.1**
Product Transfer										
(L1R is used as the worst case between L1R and L1G)										
Read L1R Data from Disk	16 bit int.	39.50	9.88	157.98	2	79.00	19.76	315.96		809.72
Read IC Data (L1R) from disk	16 bit int.	6.95	1.74	27.77	2	13.90	3.48	55.54		142.42
or Read L1G Data into memory	8 bit int.	100.47	25.12	401.87	1	100.47	25.12	401.87		1029.78
Read LPGS Process related data from disk	byte					1.50	1.50	4.00		14.50
Read MSCD/PCD/Meta/CPF from disk	byte								11.06	11.06
Total for Product Transfer (Choose between L1R and L1G)						**102.0**	**26.6**	**405.9**	**11.1**	**1055.3**
Grand Total						**148.4**	**38.2**	**591.6**	**22.1**	**1542.5**

FDDI Data Transfer for 1 WRS Scene for Anomaly Analysis										
	Type	**Bands 1-5 & 7 (M Pixels)**	**Band 6 (Lo & Hi) (M Pixels)**	**Band 8 (M Pixels)**	**Bytes/ pixel**	**Bands 1-5 & 7 (M Bytes)**	**Band 6 (Lo & Hi) (M Bytes)**	**Band 8 (M Bytes)**	**Band Independent (M Bytes)**	**Total for 1 WRS Scene (M Bytes)**
AAS										
Read 0R Data into memory	byte	39.50	9.88	157.98	1	39.50	9.88	157.98		404.86
Read IC Data (0R) into memory	byte	6.95	1.74	27.77	1	6.95	1.74	27.77		71.21
Read LPGS Process related data into memory	byte					1.50	1.50	4.00		14.50
Read 0Rc Data into memory	FP	39.50	9.88	157.98	4	158.00	39.52	631.92		1619.44
Read IC Data (0Rc) into memory	FP	6.95	1.74	27.77	4	27.80	6.96	111.08		284.84
Read 1R Data into memory	FP	39.50	9.88	157.98	4	158.00	39.52	631.92		1619.44
Read IC Data (1R) into memory	FP	6.95	1.74	27.77	4	27.80	6.96	111.08		284.84
Read L1R Data into memory	16 bit int.	39.50	9.88	157.98	2	79.00	19.76	315.96		809.72
Read IC Data (L1R) into memory	16 bit int.	6.95	1.74	27.77	2	13.90	3.48	55.54		142.42
Read L1G Data into memory	8 bit int.	100.47	25.12	401.87	1	100.47	25.12	401.87		1029.78
Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
Write LPGS Process related data to disk	byte					1.50	1.50	4.00		14.50
Total for AAS						**614.4**	**155.9**	**2453.1**	**11.1**	**6306.61**

Table 5–3. Data Volume Transferred via Disk for Nominal Processing of One WRS Scene (Raw Data) (1 of 3)

Disk I/O for 1 WRS Scene for Nominal Processing											
		Type	Bands 1-5 & 7 (M Pixels)	Band 6 (Lo & Hi) (M Pixels)	Band 8 (M Pixels)	Byte/ Pixel	Bands 1-5 & 7 (M Bytes)	Band 6 (Lo & Hi) (M Bytes)	Band 8 (M Bytes)	Band Independent (M Bytes)	Total for 1 WRS Scene (M Bytes)
Ingest Data											
	Write 0R Data to disk	byte	39.50	9.88	157.98	1	39.50	9.88	157.98		404.86
	Write IC Data (0R) to disk	byte	6.95	1.74	27.77	1	6.95	1.74	27.77		71.21
	Write MSCD/PCD/Meta/CPF to disk	byte								11.06	11.06
	Read 0R Data into memory	byte	39.50	9.88	157.98	1	39.50	9.88	157.98		404.86
	Read IC Data (0R) into memory	byte	6.95	1.74	27.77	1	6.95	1.74	27.77		71.21
	Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
	Write 0R Data to input directory	byte	39.50	9.88	157.98	1	39.50	9.88	157.98		404.86
	Write IC Data (0R) to input directory	byte	6.95	1.74	27.77	1	6.95	1.74	27.77		71.21
	Write MSCD/PCD/Meta/CPF to input directory	byte								11.06	11.06
Total for Ingestion							**139.4**	**34.9**	**557.3**	**33.2**	**1461.4**
Level 1R Process											
Process # 1											
Step 1	0R Radiometric Characterization										
	Read 0R Data into memory	byte	39.50	9.88	157.98	1	39.50	9.88	157.98		404.86
	Read IC Data (0R) into memory	byte	6.95	1.74	27.77	1	6.95	1.74	27.77		71.21
	Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
	Total for Step 1						**46.5**	**11.6**	**185.8**	**11.1**	**487.1**
Step 2	Pre-1R Correction										
	Write 0Rc Data to disk	FP	39.50	9.88	157.98	4	158.00	39.52	631.92		1619.44
	Write IC Data (0Rc) to disk	FP	6.95	1.74	27.77	4	27.80	6.96	111.08		284.84
	Write LPGS Process related data to disk	byte					1.50	1.50	4.00		14.50
	Total for Step 2						**187.3**	**48.0**	**747.0**	**0.0**	**1918.8**
Process # 2											
Step 3	0Rc Radiometric Characterization/Calibration										
	Read 0Rc Data into memory	FP	39.50	9.88	157.98	4	158.00	39.52	631.92		1619.44
	Read IC Data (0Rc) into memory	FP	6.95	1.74	27.77	4	27.80	6.96	111.08		284.84
	Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
	Write LPGS Process related data to disk	byte					1.50	1.50	4.00		14.50
	Total for Step 3						**187.3**	**48.0**	**747.0**	**11.1**	**1929.8**
Step 4	1R Correction										
	Write 1R Data to disk	FP	39.50	9.88	157.98	4	158.00	39.52	631.92		1619.44
	Write IC Data (1R) to disk	FP	6.95	1.74	27.77	4	27.80	6.96	111.08		284.84
	Write LPGS Process data to disk	byte					1.50	1.50	4.00		14.50
	Total for Step 4						**187.3**	**48.0**	**747.0**	**0.0**	**1918.8**
Process # 3											
Step 5	1R Radiometric Characterization/Correction										
	Read 1R Data into memory	FP	39.50	9.88	157.98	4	158.00	39.52	631.92		1619.44
	Read IC Data (1R) into memory	FP	6.95	1.74	27.77	4	27.80	6.96	111.08		284.84
	Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
	Write L1R Data to disk	16 bit int.	39.50	9.88	157.98	2	79.00	19.76	315.96		809.72
	Write IC Data (L1R) to disk	16 bit int.	6.95	1.74	27.77	2	13.90	3.48	55.54		142.42
	Write LPGS Process data to disk	byte					1.50	1.50	4.00		14.50
	Total for Step 5						**280.2**	**71.2**	**1118.5**	**11.1**	**2882.0**
Total for 1R Processing							**888.6**	**226.8**	**3545.3**	**33.2**	**9136.5**

Table 5–3. Data Volume Transferred via Disk for Nominal Processing of One WRS Scene (Raw Data) (2 of 3)

Disk I/O for 1 WRS Scene for Nominal Processing											
		Type	Bands 1-5 & 7 (M Pixels)	Band 6 (Lo & Hi) (M Pixels)	Band 8 (M Pixels)	Byte/ Pixel	Bands 1-5 & 7 (M Bytes)	Band 6 (Lo & Hi) (M Bytes)	Band 8 (M Bytes)	Band Independent (M Bytes)	Total for 1 WRS Scene (M Bytes)
QA for L1R											
	Read LPGS Process related data into memory	byte					1.50	1.50	4.00		14.50
	Read L1R Data into memory	16 bit int.	39.50	9.88	157.98	2	79.00	19.76	315.96		809.72
	Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
	Write LPGS Process related data to disk	byte					1.50	1.50	4.00		14.50
Total for L1R QA							**82.0**	**22.8**	**324.0**	**11.1**	**849.8**
Level 1G Process											
Step 1	Create Extended Image										
	Read 1R Data into memory	16 bit int.	39.50	9.88	157.98	2	79.00	19.76	315.96		809.72
	Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
	Write Extended Image to disk** (** Conversion factor of 2.5 = 2*1.25 to account for 25% added lines and 2 bytes)	16 bit int.	39.50	9.88	157.98	2.5	98.75	24.70	394.95		1012.15
	Write Geometric Grid to disk	byte					4.00	2.00	8.00		34.00
	Total for Step 1						**181.8**	**46.5**	**718.9**	**11.1**	**1866.9**
Step 2	Resample										
	Read Extended image into memory** (** Conversion factor of 2.5 = 2*1.25 to account for 25% added lines and 2 bytes)	16 bit int.	39.50	9.88	157.98	2.5	98.75	24.70	394.95		1012.15
	Read Geometric Grid into memory	byte					4.00	2.00	8.00		34.00
	Write L1G Data to disk	8 bit int.	100.47	25.12	401.87	1	100.47	25.12	401.87		1029.78
	Write LPGS Process related data to disk	byte					1.50	1.50	4.00		14.50
	Total for Step 2						**204.7**	**53.3**	**808.8**	**0.0**	**2090.4**
Total for 1G Processing							**386.5**	**99.8**	**1527.7**	**11.1**	**3957.4**
QA for L1G											
	Read LPGS Process related data into memory	byte					1.50	1.50	4.00		14.50
	Read L1G Data into memory	8 bit int.	100.47	25.12	401.87	1	100.47	25.12	401.87		1029.78
	Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
	Write LPGS Process related data to disk	byte					1.50	1.50	4.00		14.50
Total for L1G QA							**103.5**	**28.1**	**409.9**	**11.1**	**1069.8**
Format Product											
	(L1G is used as the worst case between L1R and L1G)										
	Read L1G Data into memory	8 bit int.	100.47	25.12	401.87	1	100.47	25.12	401.87		1029.78
	Read LPGS Process related data into memory	byte					1.50	1.50	4.00		14.50
	Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
	Write L1G Data to output directory	8 bit int.	100.47	25.12	401.87	1	100.47	25.12	401.87		1029.78
	Write LPGS Process related data to output directory	byte					1.50	1.50	4.00		14.50
	Write MSCD/PCD/Meta/CPF to output directory	byte								11.06	11.06
Total for Format Product (Choose between L1R and L1G)							**203.9**	**53.2**	**811.7**	**22.1**	**2110.7**

Table 5–3. Data Volume Transferred via Disk for Nominal Processing of One WRS Scene (Raw Data) (3 of 3)

Disk I/O for 1 WRS Scene for Nominal Processing										
	Type	Bands 1-5 & 7 (M Pixels)	Band 6 (Lo & Hi) (M Pixels)	Band 8 (M Pixels)	Byte/ Pixel	Bands 1-5 & 7 (M Bytes)	Band 6 (Lo & Hi) (M Bytes)	Band 8 (M Bytes)	Band Independent (M Bytes)	Total for 1 WRS Scene (M Bytes)
Final QA										
(L1G is used since it is the worst case between L1R and L1G)										
Read LPGS Process related data into memory	byte					1.50	1.50	4.00		14.50
Read L1G Data into memory	8 bit int.	100.47	25.12	401.87	1	100.47	25.12	401.87		1029.78
Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
Write LPGS Process related data to disk	byte					1.50	1.50	4.00		14.50
Total for Final QA (choose between L1R and L1G)						**103.5**	**28.1**	**409.9**	**11.1**	**1069.8**
Product Transfer										
(L1G is used since it is the worst case between L1R and L1G)										
Read L1R Data (L1R) from disk	8 bit int.	100.47	25.12	401.87	1	100.47	25.12	401.87		1029.78
Read LPGS Process related data from disk	byte					1.50	1.50	4.00		14.50
Read MSCD/PCD/Meta/CPF from disk	byte								11.06	11.06
Total for Product Transfer (choose between L1R and L1G)						**102.0**	**26.6**	**405.9**	**11.1**	**1055.3**
Grand Total						**2009.2**	**520.3**	**7991.5**	**143.8**	**20710.8**

Table 5–4. Data Volume Transferred via Disk for Non-nominal Processing of One WRS Scene (Raw Data)

Disk I/O for 1 WRS Scene for Anomaly Analysis										
	Type	Bands 1-5 & 7 (M Pixels)	Band 6 (Lo & Hi) (M Pixels)	Band 8 (M Pixels)	Bytes/pixel	Bands 1-5 & 7 (M Bytes)	Band 6 (Lo & Hi) (M Bytes)	Band 8 (M Bytes)	Band Independent	Total for 1 WRS Scene (M Bytes)
AAS										
Read 0R Data into memory	byte	39.50	9.88	157.98	1	39.50	9.88	157.98		404.86
Read IC Data (0R) into memory	byte	6.95	1.74	27.77	1	6.95	1.74	27.77		71.21
Read LPGS Process related data into memory	byte					1.50	1.50	4.00		14.50
Read 0Rc Data into memory	FP	39.50	9.88	157.98	4	158.00	39.52	631.92		1619.44
Read IC Data (0Rc) into memory	FP	6.95	1.74	27.77	4	27.80	6.96	111.08		284.84
Read 1R Data into memory	FP	39.50	9.88	157.98	4	158.00	39.52	631.92		1619.44
Read IC Data (1R) into memory	FP	6.95	1.74	27.77	4	27.80	6.96	111.08		284.84
Read L1R Data into memory	16 bit int.	39.50	9.88	157.98	2	79.00	19.76	315.96		809.72
Read IC Data (L1R) into memory	16 bit int.	6.95	1.74	27.77	2	13.90	3.48	55.54		142.42
Read L1G Data into memory	8 bit int.	100.47	25.12	401.87	1	100.47	25.12	401.87		1029.78
Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
Write LPGS Process related data to disk	byte					1.50	1.50	4.00		14.50
Total for AAS						**614.4**	**155.9**	**2453.1**	**11.1**	**6306.61**
Note: The same amount of data needs to be written to the disk of the AA/QA HWCI										

5.3.1.3 Data Storage

The amount of the data storage required is estimated using the spreadsheet file DATA.

The amount of the memory required varies depending on the major functions involved, the band being processed, and the size of the image. It is assumed that the processing will be performed band by band. Furthermore, for the radiometric processing, the processing will be performed one scene at a time. Therefore, only one scene worth of data will be read into memory for processing. For the geometric processing, only a subset of data (50 scan lines for example) are to be read into the memory for processing. However, the resampling will require to build the entire image (up to three scenes) in the memory. The memory estimates by function and by band for the nominal processing of one WRS scene are summarized in Table 5–5. Similar estimates for processing three WRS scenes are summarized in Table 5-6. The worst case actual image size is used in the memory estimates. Table 5-5 and Table 5-6 show that the amount of memory required to process a Band 8 image is about four times the amount required to process a Band 1 image. The memory required for the radiometric processing is about 950 MB regardless of the scene size, while the memory required for the geometric processing increases from 446 MB for one scene to 1,343 MB for three scenes. In addition, 512 MB of memory are required for the operating system. Note the data mentioned above does not include a 25 percent reserve.

Commercial off-the-shelf (COTS) software packages such as the Environment for Visualizing Images (ENVI), Interactive Data Language (IDL), Oracle, and FrameMaker will be used as the tools for visual quality assessment for the workstations of the QA/AA HWCI. Therefore, the memory requirements are driven by these software packages. It is estimated that 64 MB total memory will be required for the workstation.

The disk storage estimates for the LPGS for a daily workload of processing 25 scenes (plus reprocessing of three scenes) are summarized in Table 5–7. The estimates are based on the following assumptions:

- size of the input buffer: 12 scenes
- size of the in-process queues : 12 scenes
- size of the output buffer: 12 scenes
- trending data: 90 days
- number of scenes per day: 25 scenes
- number of reprocessing per day 3 scenes
- number of anomaly analysis 3 scenes

The worst case average image size is used in the disk storage estimates. The disk storage requirements for different workload are discussed later in Section 6.3.

Table 5–5. Memory Requirements per Band for Nominal Processing of One WRS Scene (Raw Data) (1 of 2)

Memory Requirements per Band per WRS Scene for Nominal Processing (based on actual size)								
		Bands 1-5 & 7 (M Pixels)	**Band 6 (Lo & Hi) (M Pixels)**	**Band 8 (M Pixels)**	**Byte/Pixel**	**Bands 1-5 & 8 (M Bytes)**	**Band 6 (Lo & Hi) (M Bytes)**	**Band 8 (M Bytes)**
Ingest Data								
	0R Image	39.50	9.88	157.98	1	39.50	9.88	157.98
	IC for 0R	6.95	1.74	27.77	1	6.95	1.74	27.77
	MSCD/PCD/Meta/CPF					11.06	11.06	11.06
	Total for Ingest data					57.51	22.68	196.81
Ingest Data Memory Requirements						**57.51**	**22.68**	**196.81**
L1R Processing								
Step 1	0R Radiometric Characterization							
	0R Image	39.50	9.88	157.98	1	39.50	9.88	157.98
	IC for 0R	6.95	1.74	27.77	1	6.95	1.74	27.77
	MSCD/PCD/Meta/CPF					11.06	11.06	11.06
	Total for Step 1					57.51	22.68	196.81
Step 2	Pre-1R Correction							
	0R Image	39.50	9.88	157.98	1	39.50	9.88	157.98
	IC for 0R	6.95	1.74	27.77	1	6.95	1.74	27.77
	1R Image	39.50	9.88	157.98	4	158.00	39.52	631.92
	IC for 1R	6.95	1.74	27.77	4	27.80	6.96	111.08
	LPGS Process Related Data					1.50	1.50	4.00
	MSCD/PCD/Meta/CPF					11.06	11.06	11.06
	Total for Step 2					244.81	70.66	943.81
Step 3	0Rc Radiometric Characterization							
	1R Image	39.50	9.88	157.98	4	158.00	39.52	631.92
	IC for 1R	6.95	1.74	27.77	4	27.80	6.96	111.08
	LPGS Process Related Data					1.50	1.50	4.00
	MSCD/PCD/Meta/CPF					11.06	11.06	11.06
	Total for Step 3					198.36	59.04	758.06
Step 4	1R Correction							
	1R Image	39.50	9.88	157.98	4	158.00	39.52	631.92
	IC for 1R	6.95	1.74	27.77	4	27.80	6.96	111.08
	LPGS Process Related Data					1.50	1.50	4.00
	MSCD/PCD/Meta/CPF					11.06	11.06	11.06
	Total for Step 4					198.36	59.04	758.06
Step 5	1R Radiometric Characterization/Correction							
	1R Image	39.50	9.88	157.98	4	158.00	39.52	631.92
	IC for 1R	6.95	1.74	27.77	4	27.80	6.96	111.08
	LPGS Process Related Data					1.50	1.50	4.00
	MSCD/PCD/Meta/CPF					11.06	11.06	11.06
	Total for Step 5					198.36	59.04	758.06
	(* Assume L1R image will be written to disk scan by scan)							
QA for L1R								
	L1R Image	39.50	9.88	157.98	2	79.00	19.76	315.96
	LPGS Process Related Data					1.50	1.50	4.00
	MSCD/PCD/Meta/CPF					11.06	11.06	11.06
	Total for L1R QA					91.56	32.32	331.02
L1R Processing Memory Requirements*						**244.81**	**70.66**	**943.81**
	(* Maximum of steps 1-5 and L1R QA)							

Table 5–5. Memory Requirements per Band for Nominal Processing of One WRS Scene (Raw Data) (2 of 2)

Memory Requirements per Band per WRS Scene for Nominal Processing (based on actual size)									
			Bands 1-5 & 7	**Band 6 (Lo & Hi)**	**Band 8**	**Byte/Pixel**	**Bands 1-5 & 8**	**Band 6 (Lo & Hi)**	**Band 8**
			(M Pixels)	**(M Pixels)**	**(M Pixels)**		**(M Bytes)**	**(M Bytes)**	**(M Bytes)**
L1G Processing									
Step 1 &2	Create Extended Image/Resample								
	L1R Input Buffer		5.28	1.32	21.12	4	21.12	5.28	84.48
	L1R Extended Image	1.25	6.60	1.65	26.40	4	26.40	6.60	105.60
	L1G Output Image		79.18	19.79	316.71	1	79.18	19.79	316.71
	(Use either actual or worst case average depending on L1G file size flag)								
	LPGS Process Related Data						1.50	1.50	4.00
	MSCD/PCD/Meta/CPF						11.06	11.06	11.06
	Geometric Grid						4.00	2.00	8.00
	Total for Steps 1 & 2*						122.14	40.95	445.37
	(*Assuming L1R image not to be retained)								
QA for L1G									
	L1G Image		100.47	25.12	401.87	1	100.47	25.12	401.87
	LPGS Process Related Data						1.50	1.50	4.00
	MSCD/PCD/Meta/CPF						11.06	11.06	11.06
	Total for L1G QA						113.03	37.68	416.93
L1G Processing Memory Requirements*							**122.14**	**40.95**	**445.37**
	(* Maximum of Steps 1&2 and L1G QA)								
Format Product									
Format Product									
	L1R Image		39.50	9.88	157.98	2	79.00	19.76	315.96
	IC Data (L1R)		6.95	1.74	27.77	2	13.90	3.48	55.54
	or L1G image		100.47	25.12	401.87	1	100.47	25.12	401.87
	LPGS Process Related Data						1.50	1.50	4.00
	MSCD/PCD/Meta/CPF						11.06	11.06	11.06
	Total for Format Product (max of L1R and L1G)						113.03	37.68	416.93
Final QA									
	L1R Image		39.50	9.88	157.98	2	79.00	19.76	315.96
	or L1G image		100.47	25.12	401.87	1	100.47	25.12	401.87
	LPGS Process Related Data						1.50	1.50	4.00
	MSCD/PCD/Meta/CPF						11.06	11.06	11.06
	Total for Final QA (max of L1R and L1G)						113.03	37.68	416.93
Format Product Memory Requirements*							**113.03**	**37.68**	**416.93**
	(* Maximum of Steps 1-3 & Final QA)								
Product Transfer							**minimal**	**minimal**	**minimal**

Table 5–6. Memory Requirements per Band for Nominal Processing of Three WRS Scenes (Raw Data) (1 of 2)

Memory Requirements per Band per 3 WRS Scenes for Nominal Processing (based on actual size)								
		Bands 1-5 & 7 (M Pixels)	**Band 6 (Lo & Hi) (M Pixels)**	**Band 8 (M Pixels)**	**Byte/Pixel**	**Bands 1-5 & 8 (M Bytes)**	**Band 6 (Lo & Hi) (M Bytes)**	**Band 8 (M Bytes)**
Ingest Data								
	0R Image	39.50	9.88	157.98	1	39.50	9.88	157.98
	IC for 0R	6.95	1.74	27.77	1	6.95	1.74	27.77
	MSCD/PCD/Meta/CPF					11.12	11.12	11.12
	Total for Ingest data					57.57	22.74	196.87
Ingest Data Memory Requirements						**57.57**	**22.74**	**196.87**
L1R Processing								
Step 1	0R Radiometric Characterization							
	0R Image	39.50	9.88	157.98	1	39.50	9.88	157.98
	IC for 0R	6.95	1.74	27.77	1	6.95	1.74	27.77
	MSCD/PCD/Meta/CPF					11.12	11.12	11.12
	Total for Step 1					57.57	22.74	196.87
Step 2	Pre-1R Correction							
	0R Image	39.50	9.88	157.98	1	39.50	9.88	157.98
	IC for 0R	6.95	1.74	27.77	1	6.95	1.74	27.77
	1R Image	39.50	9.88	157.98	4	158.00	39.52	631.92
	IC for 1R	6.95	1.74	27.77	4	27.80	6.96	111.08
	LPGS Process Related Data					4.50	4.50	12.00
	MSCD/PCD/Meta/CPF					11.12	11.12	11.12
	Total for Step 2					247.87	73.72	951.87
Step 3	0Rc Radiometric Characterization							
	1R Image	39.50	9.88	157.98	4	158.00	39.52	631.92
	IC for 1R	6.95	1.74	27.77	4	27.80	6.96	111.08
	LPGS Process Related Data					4.50	4.50	12.00
	MSCD/PCD/Meta/CPF					11.12	11.12	11.12
	Total for Step 3					201.42	62.10	766.12
Step 4	1R Correction							
	1R Image	39.50	9.88	157.98	4	158.00	39.52	631.92
	IC for 1R	6.95	1.74	27.77	4	27.80	6.96	111.08
	LPGS Process Related Data					4.50	4.50	12.00
	MSCD/PCD/Meta/CPF					11.12	11.12	11.12
	Total for Step 4					201.42	62.10	766.12
Step 5	1R Radiometric Characterization/Correction							
	1R Image	39.50	9.88	157.98	4	158.00	39.52	631.92
	IC for 1R	6.95	1.74	27.77	4	27.80	6.96	111.08
	LPGS Process Related Data					4.50	4.50	12.00
	MSCD/PCD/Meta/CPF					11.12	11.12	11.12
	Total for Step 5					201.42	62.10	766.12
	(* Assume L1R image will be written to disk scan by scan)							
QA for L1R								
	L1R Image	39.50	9.88	157.98	2	79.00	19.76	315.96
	LPGS Process Related Data					4.50	4.50	12.00
	MSCD/PCD/Meta/CPF					11.12	11.12	11.12
	Total for L1R QA					94.62	35.38	339.08
L1R Processing Memory Requirements*						**247.87**	**73.72**	**951.87**
	(* Maximum of steps 1-5 and L1R QA)							

Table 5–6. Memory Requirements per Band for Nominal Processing of Three WRS Scenes (Raw Data) (2 of 2)

Memory Requirements per Band per WRS Scene for Nominal Processing (based on actual size)									
			Bands 1-5 & 7 (M Pixels)	**Band 6 (Lo & Hi) (M Pixels)**	**Band 8 (M Pixels)**	**Byte/Pixel**	**Bands 1-5 & 8 (M Bytes)**	**Band 6 (Lo & Hi) (M Bytes)**	**Band 8 (M Bytes)**
L1G Processing									
Step 1 &2	Create Extended Image/Resample								
	L1R Input Buffer		5.28	1.32	21.12	4	21.12	5.28	84.48
	L1R Extended Image	1.25	6.60	1.65	26.40	4	26.40	6.60	105.60
	L1G Output Image		301.40	75.35	1205.60	1	301.40	75.35	1205.60
	(Use either actual or worst case average depending on L1G file size flag)								
	LPGS Process Related Data						4.50	4.50	12.00
	MSCD/PCD/Meta/CPF						11.12	11.12	11.12
	Geometric Grid						4.00	2.00	8.00
	Total for Steps 1 & 2*						347.42	99.57	1342.32
	(*Assuming L1R image not to be retained)								
QA for L1G									
	L1G Image		301.40	75.35	1205.60	1	301.40	75.35	1205.60
	LPGS Process Related Data						4.50	4.50	12.00
	MSCD/PCD/Meta/CPF						11.12	11.12	11.12
	Total for L1G QA						317.02	90.97	1228.72
L1G Processing Memory Requirements*							**347.42**	**99.57**	**1342.32**
	(* Maximum of Steps 1&2 and L1G QA)								
Format Product									
Format Product									
	L1R Image		39.50	9.88	157.98	2	79.00	19.76	315.96
	IC Data (L1R)		6.95	1.74	27.77	2	13.90	3.48	55.54
	or L1G image		301.40	75.35	1205.60	1	301.40	75.35	1205.60
	LPGS Process Related Data						4.50	4.50	12.00
	MSCD/PCD/Meta/CPF						11.12	11.12	11.12
	Total for Format Product (max of L1R and L1G)						317.02	90.97	1228.72
Final QA									
	L1R Image		39.50	9.88	157.98	2	79.00	19.76	315.96
	or L1G image		301.40	75.35	1205.60	1	301.40	75.35	1205.60
	LPGS Process Related Data						4.50	4.50	12.00
	MSCD/PCD/Meta/CPF						11.12	11.12	11.12
	Total for Final QA (max of L1R and L1G)						317.02	90.97	1228.72
Format Product Memory Requirements*							**317.02**	**90.97**	**1228.72**
	(* Maximum of Steps 1-3 & Final QA)								
Product Transfer							**minimal**	**minimal**	**minimal**

Table 5–7. Disk Storage Requirements for Daily Workload of 25 Scenes (Raw Data) (1 of 2)

Disk Storage						
	Mega Pixels	Bytes/Pixel	Total Mega Bytes per item	Frequency/ Occurrence	Total in Mega Bytes	**Total in Giga Byte**
Output Buffer						
# of Work Orders				4		
Scene size (number of WRS scene per work order)				3		
0R data	404.83	1	404.83	12	4857.96	
IC data (0R)	71.16	1	71.16	12	853.92	
0Rc data	404.83	4	1619.32	12	19431.84	
IC data (0Rc)	71.16	4	284.64	12	3415.68	
1R data	404.83	4	1619.32	12	19431.84	
IC data (1R)	71.16	4	284.64	12	3415.68	
L1R Image	404.83	2	809.66	12	9715.92	
IC data (L1R)	71.16	2	142.32	12	1707.84	
L1G Image	1029.80	1	1029.80	12	12357.60	
Geometric Grid			34.00	12	408.00	
MSCD/PCD/Meta Data/CPF			11.06	12	132.72	
LPGS Process related data			14.50	12	174.00	
Total for output buffer					**75903**	**75.91**
Scenes currently being processed						
Number of work order being processed in parallel				4		
Scene size (number of WRS scene per work order)				3		
0R data	404.83	1	404.83	12	4857.96	
IC data (0R)	71.16	1	71.16	12	853.92	
0Rc data	404.83	4	1619.32	12	19431.84	
IC data (0Rc)	71.16	4	284.64	12	3415.68	
1R data	404.83	4	1619.32	12	19431.84	
IC data (1R)	71.16	4	284.64	12	3415.68	
L1R Image	404.83	2	809.66	12	9715.92	
IC data (L1R)	71.16	2	142.32	12	1707.84	
L1G Image	1029.80	1	1029.80	12	12357.60	
Geometric Grid			34.00	12	408.00	
MSCD/PCD/Meta Data/CPF			11.06	12	132.72	
LPGS Process related data			14.50	12	174.00	
Total for scene being processed					**75903**	**75.91**
0R in queue waiting for processing						
Number of work order being processed in parallel				4		
Scene size (number of WRS scene per work order)				3		
0R data	404.83	1	404.83	12	4857.96	
IC data (0R)	71.16	1	71.16	12	853.92	
MSCD/PCD/Meta Data/CPF			11.06	12	132.72	
Total for 0R in queue					**5844.6**	**5.85**
Trending Data						
Number of scenes per day				28		
Number of days of trending data				90		
Trending data			.15	2520	378	
Total for trending data					**378**	**.38**
Database			3000	1	**3000**	**3.0**

Table 5–7. Disk Storage Requirements for Workload of 25 Scenes per Day (Raw Data) (2 of 2)

Disk Storage						
	Mega Pixels	Bytes/Pixel	Total Mega Bytes per item	Frequency/ Occurrence	Total in Mega Bytes	**Total in Giga Byte**
Data generated for anomaly analysis						
# of anomaly requests				1		
Average size of image (# of WRS scenes)				3		
Additional space for the one being analyzed (per request)				1500	Mega Bytes	
Number of passes				2		
0R data	404.83	1	404.83	6	2428.98	
IC data (0R)	71.16	1	71.16	6	426.96	
0Rc data	404.83	4	1619.32	6	9715.92	
IC data (0Rc)	71.16	4	284.64	6	1707.84	
1R data	404.83	4	1619.32	6	9715.92	
IC data (1R)	71.16	4	284.64	6	1707.84	
L1R Image	404.83	2	809.66	6	4857.96	
IC data (L1R)	71.16	2	142.32	6	853.92	
L1G Image	1029.80	1	1029.80	6	6178.80	
MSCD/PCD/Meta Data/CPF			11.06	6	66.36	
LPGS Process related data			14.50	6	87.00	
Additional space for the one being analyzed			**1500.00**	3	**4500.00**	
Total for data generated for anomaly analysis					**42247.50**	**42.25**
Total for L1 Processing HWCI						**203.30**

5.3.2 Spreadsheet Model Results—With Error Margins and Overheads

The raw data obtained in Section 5.2.2 do not include error margins, operating system overheads, and additional reserves required by the F&PRS. The raw data are summarized in Table 5–8 for the L1 Processing HWCI and in Table 5–9 for the QA/AA HWCI. These raw data are aggregated to obtain the total values. The number of operations, processing time, disk I/O, and FDDI I/O are based on one WRS scene, the memory requirements are based on a three-scene product request, and the disk storage is based on a workload of processing 25 scenes (plus reprocessing of three scenes) per day.

The error margins, operating system/program overheads, and additional reserves are then added to the raw total values to yield the overall processing time, amount of data transfer for the FDDI and disk, and amount of memory and disk storage requirements. The results are shown in Table 5–10 for the L1 Processing HWCI and in Table 5–11 for the QA/AA HWCI. Note that the total processing time combines the extrapolated processing time for the geometric processing and the processing time for the radiometric processing, which is calculated from the instruction counts and the CPU processing speed. Except for the disk storage, the calculations are made for individual bands and totaled for the entire scene. The CPU overheads due to data transfer for the FDDI and disk are not included in these tables.

Table 5–8. Summary of Results (Raw Data Without Error Margins, Overheads) for L1 Processing HWCI

Level 1 Processing HWCI (Nominal Processing) (Data Only) (no error margin, no operating system overhead)						
	Ingest Data	L1R Processing	L1G Processing	Format Product	Transfer Product	**Total**
Number of Operations (Million Ops) for 1 WRS Scene						
Bands 1-5 & 7		14622.29				**14622.29**
Band 6 (Lo & Hi)		4026.27				**4026.27**
Band 8		90206.37				**90206.37**
Total for 1 WRS Scene		181965.66				**181965.66**
Processing Time (seconds) (extrapolated from benchmark results) for 1 WRS Scene						
Bands 1-5 & 7			167.40			**167.40**
Band 6 (Lo & Hi)			125.55			**125.55**
Band 8			669.60			**669.60**
Total for 1 WRS Scene			1799.55			**1799.55**
Memory Requirements (Mega Bytes) for 1 Product Request (3 scenes)						
Bands 1-5 & 7	57.57	247.87	347.43	317.03	minimal	
Band 6 (Lo & Hi)	22.74	73.72	99.58	90.98	minimal	
Band 8	196.87	951.87	1342.33	1228.73	minimal	
Overall	**196.87**	**951.87**	**1342.33**	**1228.73**	**minimal**	
Disk IO (Mega Bytes) for 1 WRS Scene						
Bands 1-5 & 7	139.35	970.55	489.94	307.41	101.97	**2009.22**
Band 6 (Lo & Hi)	34.86	249.54	127.90	81.36	26.62	**520.28**
Band 8	557.25	3869.21	1937.60	1221.61	405.87	**7991.54**
Band Independent	33.18	44.24	22.12	33.18	11.06	**143.78**
Total for 1 WRS Scene	1461.39	9986.29	5027.26	3180.61	1055.37	**20710.92**
FDDI IO (Mega Bytes) for 1 WRS Scene						
Bands 1-5 & 7	46.45				101.97	**148.42**
Band 6 (Lo & Hi)	11.62				26.62	**38.24**
Band 8	185.75				405.87	**591.62**
Band Independent	11.06				11.06	**22.12**
Total for 1 WRS Scene	487.13				1055.37	**1542.50**
Disk Storage (Giga Bytes) for Workload of 25 Scenes/Day (plus reprocessing of 3 scenes)						
Total						**203.30**

Table 5–9. Summary of Results (Raw Data Without Error Margins, Overheads) for QA/AA HWCI

Quality Assessment/Anomaly Analysis HWCI (Data Only) (no error margin, no operating system overhead)	
	Total
Disk I/O (Mega Bytes) per WRS Scene	
Bands 1-5 & 7	614.42
Band 6 (Lo & Hi)	155.94
Band 8	2453.12
Band Independent	11.06
Total for 1 WRS Scene	**6306.64**
FDDI I/O (Mega Bytes) per WRS Scene	
Bands 1-5 & 7	614.42
Band 6 (Lo & Hi)	155.94
Band 8	2453.12
Band Independent	11.06
Total for 1 WRS Scene	**6306.64**

Table 5–10. Summary of Results (Data With Error Margins, Overheads) for L1 Processing HWCI

Level 1 Processing HWCI (Nominal Processing) (with error margin and operating system overhead)									
	Total without Error Margin Overhead	Error Margin	Total with Error Margin	Operating System Overhead	Total with Error Margin & O/S & Pgm	Additional Requirement per F&PRS	Total with Additional Requirement	**Overall**	
Number of Operations (Million Ops) (estimated) for 1 WRS Scene									
Bands 1-5 & 7	14622.29	50%	21933.43	0	21933.43				
Band 6 (Lo & Hi)	4026.27	50%	6039.41	0	6039.41				
Band 8	90206.37	50%	135309.56	0	135309.56				
Total for 1 WRS Scene	181965.66	50%	272948.49	0	272948.49				
Processing Time (seconds) (extrapolated from benchmark results) for 1 WRS Scene									
Bands 1-5 & 7	167.40	0%	167.40	0	167.40				
Band 6 (Lo & Hi)	125.55	0%	125.55	0	125.55				
Band 8	669.60	0%	669.60	0	669.60				
Total for 1 WRS Scene	1799.55	0%	1799.55	0	1799.55				
Total Processing Time (seconds) for 1 WRS Scene		**0.0102564**	**micro seconds/ops**						
(Estimated number of ops * processing speed + extrapolated benchmark result)									
Bands 1-5 & 7			392.36		392.36	0%	392.36		
Band 6 (Lo & Hi)			187.49		187.49	0%	187.49		
Band 8			2057.39		2057.39	0%	2057.39		
Total for 1 WRS Scene			4599.02		4599.02	0%	4599.02	**4599.02**	**76.65 minutes**
Memory Requirements (Mega Bytes) for 1 Product Request (3 scenes)									
L1R Processing									
Bands 1-5 & 7	247.87	0%	247.87	40	287.87	25%	359.84		
Band 6 (Lo & Hi)	73.72	0%	73.72	40	113.72	25%	142.15		
Band 8	951.87	0%	951.87	40	991.87	25%	1239.84		
Overall	951.87	0%	951.87	40	991.87	25%	1239.84	**1239.84**	**Mega Bytes**
L1G Processing									
Bands 1-5 & 7	347.43	0%	347.43	40	387.43	25%	484.29		
Band 6 (Lo & Hi)	99.58	0%	99.58	40	139.58	25%	174.48		
Band 8	1342.33	0%	1342.33	40	1382.33	25%	1727.91		
Overall	1342.33	0%	1342.33	40	1382.33	25%	1727.91	**1727.91**	**Mega Bytes**
Disk I/O (Mega Bytes) for 1 WRS Scene									
Bands 1-5 & 7	2009.22	10%	2210.14	0	2210.14	0%	2210.14		
Band 6 (Lo & Hi)	520.28	10%	572.31	0	572.31	0%	572.31		
Band 8	7991.54	10%	8790.69	0	8790.69	0%	8790.69		
Band Independent	143.78	10%	158.16	0	158.16	0%	158.16		
Total for 1 WRS Scene	20710.92	10%	22782.01	0	22782.01	0%	22782.01	22782.01	Mega Bytes
FDDI I/O (Mega Bytes) for 1 WRS Scene									
Bands 1-5 & 7	148.42	10%	163.26	0	163.26	0%	163.26		
Band 6 (Lo & Hi)	38.24	10%	42.06	0	42.06	0%	42.06		
Band 8	591.62	10%	650.78	0	650.78	0%	650.78		
Band Independent	22.12	10%	24.33	0	24.33	0%	24.33		
Total for 1 WRS Scene	1542.50	10%	1696.75	0	1696.75	0%	1696.75	1696.75	Mega Bytes
Disk Storage (Giga Bytes) for Workload of 25 Scenes/Day (plus reprocessing of 3 scenes)									
Total	203.30	0%	203.30	0.00	203.30	25%	254.13	254.13	Giga Bytes

Table 5–11. Summary of Results (Data With Error Margins, Overheads) for QA/AA HWCI

Quality Assessment/Anomaly Analysis HWCI (with error margin and operating system overhead)									
	Total without Error Margin Overhead	Error Margin	Total with Error Margin	Operating System Overhead	Total with Error Margin & O/S & Pgm	Additional Requirement per F&PRS	Total with Additional Requirement	**Overall**	
Disk I/O (Mega Bytes) per WRS Scene									
Bands 1-5 & 7	614.42	10%	675.86	0	675.86	0%	675.86		
Band 6 (Lo & Hi)	155.94	10%	171.53	0	171.53	0%	171.53		
Band 8	2453.12	10%	2698.43	0	2698.43	0%	2698.43		
Band Independent	11.06	10%	12.17	0	12.17	0%	12.17		
Total for 1 WRS Scene	6306.64	10%	6937.30	0	6937.30	0%	6937.30	6937.30	Mega Bytes
FDDI I/O (Mega Bytes) per WRS Scene									
Bands 1-5 & 7	614.42	10%	675.86	0	675.86	0%	675.86		
Band 6 (Lo & Hi)	155.94	10%	171.53	0	171.53	0%	171.53		
Band 8	2453.12	10%	2698.43	0	2698.43	0%	2698.43		
Band Independent	11.06	10%	12.17	0	12.17	0%	12.17		
Total for 1 WRS Scene	6306.64	10%	6937.30	0	6937.30	0%	6937.30	6937.30	Mega Bytes

5.3.3 Spreadsheet Model Results—Total Service Time

The total service time, which includes the processing time, CPU overheads due to data transfer, and data transfer time for nominal processing of one WRS scene with one CPU is about 90.49 minutes and is shown in Table 5–12. The time it takes to transfer data from the L1 Processing HWCI to the QA/AA HWCI for the anomaly analysis is about 31.75 minutes for one WRS scene and is shown in Table 5–13. This transfer time includes transferring all files such as 0R product, L1R product, L1G product, and all intermediate files to be used for analysis. Note that the time it takes to display the image on the workstation is not included.

5.3.4 Spreadsheet Model Results—Disk and Memory Requirements

The disk and memory requirements for are summarized in Table 5–14. The total disk requirements are 254.13 GB for a workload of processing 25 scenes (plus reprocessing of three scenes) per day. (refer to Section 5.3.1.3 for assumptions).

The memory requirements for the L1 Processing HWCI are based on the amount of memory required for processing Band 8 image. 1.24 GB of memory are required for the radiometric processing of a product request regardless of the image size, while 1.73 GB of memory are required for the geometric processing of a three-scene product request. In addition, 512 MB of memory are also required for the operating system.

Table 5–12. Total Service Time for Processing One WRS Scene With One CPU

Level 1 Processing HWCI (Nominal Processing) - Process/Data Transfer Time (for 1 WRS Scene) CPU performance degradation factor = 0%						
in minutes	**Ingest Data**	**L1R Process**	**L1G Process**	**Format Product**	**Transfer Product**	**Total**
CPU Time						
Application	negligible	46.66	29.99	negligible	negligible	76.65
Overhead associated with FDDI data transfer	0.24	0.00	0.00	0.00	0.52	0.76
Overhead associated with RAID data transfer	0.27	1.88	0.95	0.60	0.20	3.89
Subtotal	**0.51**	**48.54**	**30.94**	**0.60**	**0.72**	**81.30**
Data Transfer Time						
FDDI	1.19	0.00	0.00	0.00	2.58	3.77
RAID	0.38	2.62	1.32	0.83	0.28	5.42
Subtotal	**1.57**	**2.62**	**1.32**	**0.83**	**2.86**	**9.19**
Total	**2.09**	**51.15**	**32.25**	**1.43**	**3.57**	**90.49**

Table 5–13. Time for Transferring One WRS Scene to the QA/AA HWCI for Non-nominal Processing

Quality Assessment/Anomaly Analysis HWCI - Data Transfer Time (for 1 WRS Scene) CPU performance degradation factor = 0%			
	Time (seconds)	**Time (minutes)**	**Data Volume (Mega Byte)**
FDDI data transfer	924.97	15.42	6937.30
RAID disk transfer	99.10	1.65	6937.30
W/S O2 disk transfer	346.87	5.78	6937.30
Origin 2000 CPU O/H associated with FDDI data transfer	185.23	3.09	6937.30
Origin 2000 CPU O/H associated with disk data transfer	71.15	1.19	6937.30
W/S O2 CPU O/H associated with FDDI data transfer	185.23	3.09	6937.30
W/S O2 CPU O/H associated with disk data transfer	92.50	1.54	6937.30
Total	1905.04	31.75	

Table 5–14. Memory and Disk Storage Requirements

	for	Amount	
Memory Requirement	L1R Processing	1.24	G Bytes
	L1G Processing	1.73	G Bytes
Disk Space Requirement	25 scenes per day (plus reprocessing of 3 scenes)	254.13	G Bytes